Appendix I: Mapping and Analyses of Geomorphic Units Using ArcGIS

Table of Contents

List of Tables

List of Figures (at end of appendix)

1.0 Overview of Geomorphic Mapping

Geomorphic mapping in ArcGIS was used to evaluate channel position, sediment bars, vegetation, and general characteristics of the channel to investigate the possibility of trends that could indicate morphological response to changes in woody debris, vegetation, sediment supply and transport capacity. This appendix provides a description of geomorphic map units delineated within the study reach using rectified aerial photographs taken in 1939, 1952, 1958, 1962, 1973, 1982, 1994, 1998, 2001, and 2002 and rectified cadastral survey maps from 1897, 1906, and 1929 (see Appendix H for information on rectification). This appendix also describes the geologic units discussed in the geology appendix.

For most geomorphic map units, the study reach was broken into three sections (upper, middle, and lower) based on geomorphic differences (Table I.1). The boundary between the upper and middle sections occurs at the location of a large bedrock feature on the north side of the Quinault River (RK14). The boundary between the middle and lower sections occurs at a location thought to be near the upstream end of present delta processes occurring as a result of Lake Quinault (RK 2). The boundary between the lower and middle section is also unique in that it has the downstream end of a large, historical alluvial fan from the Finley Creek drainage. Mapping was done on all of the photographs and maps, except as indicated.

Table I.1. Reach boundaries for study area between Lake Quinault (RK 0) and the Forks (RK 18.1).

Lower Reach	Middle Reach	Upper Reach - Downstream Section (DS)	Upper Reach - Upstream Section (US)
RK 0 to 2	RK 2 to 14	RK 14 to 16	RK 16 to 18.1

All of the aerial photographs cover the entire study reach except for the 1962 and 1998 aerial photographs, which only cover the area from Lake Quinault upstream to about RK 16. Some of the geomorphic mapping was compared on a decadal time scale, so results from 1962 and 1998 were not needed. Other comparisons required results from all aerial photographs. To allow comparison between mapping units, the Upstream Reach was subdivided at RK 16 into two sections, with only the downstream section containing 1962 and 1998 photography. The 1929 map covers the entire study reach. The 1906 map covers the Quinault River upstream of about RK 7.5 to RK 18.1, and the 1897 map cover the channel downstream of RK 7.5 to Lake Quinault.

The Quinault River is very dynamic and it is not uncommon for the river to change positions and geomorphic features one or more times during a winter flood season. Because the mapping used aerial photographs spaced about every ten years apart, the results are meant to look at average characteristics and trends of the river over decadal time scales rather than characterizing the exact frequency of changes. For example, the rate at which the channel re-occupies the floodplain represents a minimum rate because there could be more frequent changes between photographs. However, major channel changes were fairly obvious even on decadal time scales and could be reasonably tracked by looking at growth and removal of vegetated surfaces. Additionally, many mapping parameters looked at total change between photographs, such as terrace bank erosion or delta growth, which can be more easily measured on a decadal time scale when using aerial photography.

The historical maps have the most uncertainty associated with them. This is because geomorphic features distinguishable on the aerial photographs had to be interpreted from the maps and because these maps contained errors associated with reproduction. The majority of aerial photographs had reasonable clarity to distinguish geomorphic mapping units. The 1939 photographs were the most challenging due to more areas of distortion that were difficult to interpret. In cases of uncertainty, the areas were tracked through time to try and establish if the interpretation on a particular photograph or map was reasonable. For more recent photographs from 2001 and 2002, field checking was utilized along with Lidar data from October 2000.

2.0 Channel Units within HCMZ

The historical channel migration zone is composed of a series of channel and vegetated areas. Several types of channels were delineated on the aerial photographs (Figure I.1; Table I.2). The ability to distinguish the units depends on the quality of the photographs and relies on the interpretation and consistency of the individual doing the mapping. The newer photographs have better resolution and contrast. Each unit, except the active channel, includes areas of variable relative age, which could be distinguished if larger-scale mapping was done.

The low-flow and active channels (where shown by the presence of unvegetated bars) were traced on the older maps to supplement the mapping done on the aerial photographs. The quality of the historical mapping is unknown, but, in general, the channels fall within the 1939 HCMZ providing a cursory-level check that the channel locations are reasonable. Evidence of some of the channels delineated on the older maps is still present on the 1939 aerial photographs, even if they are vegetated by that time.

Table I.2. Characteristics of channel map units

Map Unit	Appearance on Aerial Photographs	Geomorphic Interpretation	Relative Age
Low-flow Channel	Wetted channel at the time the photographs were taken, which was typically during low-flow conditions	Deepest part of the active channel that is wetted even at the lowest flows	Active; conveys water throughout the year
Active Channel	Area that is unvegetated adjacent to the low-flow channel	Channel that conveys the majority of the river's bed load	Active; conveys most of the flow
Unvegetated Channel	Area that is primarily unvegetated adjacent to the active channel (bars); includes the active channel	Unvegetated bars adjacent to the active channel; area coveys flow at higher discharges; lack of vegetation suggests area receives flows at least once, and probably several times, per year	Active; conveys higher flows, probably at least once, and probably several times, per year
Slightly Vegetated Channel	Area that has scattered vegetation and is adjacent to the unvegetated channel at some point;	Slightly vegetated bars and channels related to the unvegetated channel; overflow channels; convey flow at the highest discharges; the presence of some vegetation suggests that the area receives flow less often than the unvegetated channel so that the area has begun to revegetate	Active or recently active; carries highest flows at most a few times per year; may not have conveyed flow for a few months
Old Channel (partially vegetated)	Area that has continuous areas of vegetation but also open areas	Old channels (mostly unvegetated channels at one time) that have not conveyed enough flow to disrupt vegetation, so that the area is beginning to revegetate; unvegetated areas are still present	No longer active; probably has not conveyed significant flow for at least a year, possibly several years
Side Channel – Wide	Wide channels through vegetated areas; channels wide enough or area is open enough so that water is visible in the channels; channels may include adjacent unvegetated bars	Side channels of the Quinault River; connected both upstream and downstream to the main channel; may have once been an unvegetated channel; location through a vegetated area suggests that only a small portion of the Quinault River flow is conveyed by these channels; water may also have a ground water source	Active, often a former location of the main channel
Side Channel – Narrow	Narrow channels through vegetated areas; channels usually too narrow or through vegetation too dense to determine if water is present in the channel; channels visible as sinuous breaks in vegetation (usually shrubby or mixed units)	Side channels of the Quinault River; usually, but not always, connected both upstream and downstream to the main channel; channel may convey surface flow, or groundwater, or both	Active
Tributary Channel	Unvegetated channel of major tributaries to the Quinault River; includes the active channel and adjacent unvegetated bars (if present); only that portion within the HCMZ is shown	Tributary channel that conveys most of the flow from that tributary to the Quinault River	Active; conveys flow at all discharges

2.1 Active Channel Results

The area within the HCMZ occupied by the active channel was computed for each year (Table I.3). Average widths of the active channels of the Quinault River were also computed by dividing the total area of the unvegetated channel for each reach by the length of the center line (Figure I.2; Table I.4). Center lines were mapped along the approximate center of the unvegetated channels.

Table I.3. Area of active channels as a percent of HCMZ area for each reach by year (Note that only RK 14 to 16 is included for Upper Reach in 1962 and 1998)

	Active Channel Area as Percent of HCMZ		
Year	**Upper Reach**	**Middle Reach**	**Lower Reach**
1939	28	28	19
1952	19	22	24
1958	32	29	20
1962	30	28	23
1973	23	20	23
1982	22	18	14
1994	22	22	13
1998	16	19	12
2001	26	25	21
2002	26	17	13

Table I.4. Average widths of active channels for each reach

	Average Active Channel Width (m)		
Year	**Upper Reach**	**Middle Reach**	**Lower Reach**
1897		181	88
1906			
1929	102	116	188
1939	100	142	112
1952	80	114	157
1958	134	160	134
1962	162	159	145
1973	98	118	160
1982	93	109	107
1994	96	137	105
1998	82	124	98
2001	117	160	167
2002	113	109	123

2.2 Unvegetated Channel Results

The area within the HCMZ occupied by the unvegetated channel was computed for each year (Table I.5). Average widths of the unvegetated channels of the Quinault River were also computed by dividing the total area of the unvegetated channel for each reach by the length of the center line (Figure I.2; Table I.6). Center lines were mapped along the approximate center of the unvegetated channels.

Table I.5. Area of unvegetated channels as a percent of HCMZ area for each reach by year (Note that only RK 14 to 16 is included for Upper Reach in 1962 and 1998)

	Unvegetated Channel as Percent of HCMZ		
Year	**Upper Reach**	**Middle Reach**	**Lower Reach**
1939	52	50	42
1952	34	34	35
1958	56	55	41
1962	48	49	38
1973	33	38	35
1982	41	38	30
1994	47	44	29
1998	61	45	32
2001	47	44	33
2002	44	42	30

Table I.6. Average widths of unvegetated channels for each reach

	Average Unvegetated Channel Width (includes Active Channel) (m)		
Year	**Upper Reach**	**Middle Reach**	**Lower Reach**
1897	No Data		
1906	237	350	
1929	252	319	204
1939	190	260	251
1952	141	178	229
1958	231	299	273
1962	258	279	240
1973	139	225	246
1982	177	235	220
1994	205	273	232
1998	312	298	257
2001	210	288	266
2002	197	271	286

The temporal and spatial relationships of the mapped unvegetated channels were compared to determine the rate at which the floodplain is reworked (Tables 7 and 8). Shapefiles for the unvegetated channels for each year were converted to a raster using spatial analyst in ARC. A value of 1 was assigned to each pixel that was part of the unvegetated channel and a value of 0 was assigned to areas outside of the unvegetated channel but within the 2002 HCMZ. Rasters were summed using the raster calculator in spatial analyst in ARC to determine how many times a pixel (an area) had been part of the unvegetated channel for the 10 years for which we have aerial photographs. The areas where the channel has been most often are the ones that are shown as most active (Figure 17 in main report).

Table I.7. Areas reworked by the unvegetated channel of the Quinault River for each reach and the entire study reach by year

Year	Total Area Reworked (m^2)			
	Upper Reach	Middle Reach	Lower Reach	Total for Study Reach
2002	744,686	2,893,006	504,630	4,142,322
2001	861,429	3,299,732	614,447	4,775,608
1998	919,133	3,582,131	681,377	5,182,641
1994	984,801	3,962,980	725,228	5,673,009
1982	1,115,839	4,422,008	846,092	6,383,939
1973	1,151,116	4,841,374	998,122	6,990,612
1962	1,260,427	5,197,089	1,144,173	7,601,688
1958	1,422,451	5,479,025	1,261,637	8,163,113
1952	1,451,282	5,508,172	1,295,716	8,255,169
1939	1,509,714	5,704,403	1,376,170	8,590,287
1929	1,629,583	6,304,371	1,387,030	9,320,984
1906	1,660,306	6,533,372		8,193,678

Table I.8. Areas reworked by the unvegetated channel of the Quinault River as a percent of the total 2002 HCMZ area for each reach and the entire study area by year and time before present

Year	Percent of 2002 HCMZ			Cumulative Total Area Reworked for Study Reach	Time: Years Before 2002
	Upper Reach	Middle Reach	Lower Reach		
2002	44	42	30	40	0
2001	51	48	36	46	1
1998	55	52	40	50	4
1994	59	57	43	55	8
1982	66	64	50	62	20
1973	68	70	59	68	29
1962	75	75	67	74	40
1958	85	79	74	79	44
1952	86	80	76	80	50
1939	90	83	81	84	63
1929	97	91	81	91	73
1906	99	95	No data	96	96

2.3 Unvegetated and Slightly Vegetated Channel Results

Because the distinction between unvegetated and slightly vegetated channels is often hard to determine, the total area of both channels was also computed to look for trends in channel properties within the HCMZ (Table I.9).

Table I.9. Area of unvegetated and slightly vegetated channels as a percent of HCMZ area for each reach by year
(Note that only RK 14 to 16 is included for Upper Reach in 1962 and 1998)

	Unvegetated and Slightly Vegetated Channels as Percent of HCMZ		
Year	Upper Reach	Middle Reach	Lower Reach
1939	64	59	53
1952	50	50	46
1958	60	59	46
1962	66	59	45
1973	39	44	42
1982	43	41	33
1994	50	46	34
1998	64	49	35
2001	53	47	35
2002	48	43	31

2.4 Side Channel Results

Side channels were generally consistent in their formation process over time except for the side channels at the base of the Finley Creek alluvial fan and from the Big Creek tributary channel. The total side channel length for a given reach including the Finley Creek and Big Creek areas are included in Table I.10 and these are excluded in Table I.11 for comparative analysis. The narrow side channel lengths were also computed and are listed in Table I.12.

Table I.10. Lengths of wide (prominent) side channels for each reach by year
(Note that only RK 14 to 16 is included for Upper Reach in 1962 and 1998)

	Prominent Side Channel Length (Big Creek & Finley Creek not included)									
Reach	1939	1952	1958	1962	1973	1982	1994	1998	2001	2002
Lower Reach	1142	0	2382	758	1763	0	1141	2770	2364	2859
Middle Reach	2605	5971	5997	4086	5245	5520	7697	6701	8860	12323
Upper Reach DS	0	0	204	0	2101	1307	1468	415	515	0
Upper Reach US	586	662	660	-	1447	1692	600	-	589	612

Table I.11. Lengths of wide (prominent) side channels and tributaries Big Creek and Finley Creek for each reach by year
(Note that only RK 14 to 16 is included for Upper Reach in 1962 and 1998)

	Prominent Side Channel Length (Includes Big Creek & Finley Creek Channels)									
Reach	1939	1952	1958	1962	1973	1982	1994	1998	2001	2002
Lower Reach	1142	0	2382	758	1763	0	1141	2770	2364	2859
Middle Reach	3494	8301	6912	4981	7474	9165	9731	8739	10898	14366
Upper Reach DS	0	0	204	0	2101	1307	1468	415	515	0
Upper Reach US	586	662	660	-	1447	1692	600	-	589	612

Table I.12. Lengths of narrower side channels for each reach by year (Note that only RK 14 to 16 is included for Upper Reach in 1962 and 1998)

Reach	Narrower Side Channel Length (Includes Big Creek & Finley Creek Channels)									
	1939	**1952**	**1958**	**1962**	**1973**	**1982**	**1994**	**1998**	**2001**	**2002**
Lower Reach	341	2906	1987	192	1739	2274	3630	3481	1193	4774
Middle Reach	2141	4032	2302	3775	7740	8077	7864	10311	8713	14760
Upper Reach DS	907	536	969	246	966	1841	759	888	923	2812
Upper Reach US	982	1230	1330	-	1383	1503	1748	-	985	2391

3.0 Vegetation Map Units within HCMZ

It was of interest to evaluate the stability of vegetated surfaces over time. Several types of vegetated surfaces that are outside of the channel units but within the HCMZ were delineated on the aerial photographs (Figure I.1; Table I.13). Vegetation categories were based on general characteristics rather than specific species because of the difficulty in discerning species in historical photographs solely based on planview appearance. The vegetation map units are more subjective in their delineation than the channel map units. The ability to distinguish the units depends on the quality of the photographs. The newer photographs have better resolution and contrast. Vegetation types are more easily distinguished on some photographs than on others. In addition, the units are often gradational over area and time, so that the contact between units may be difficult to discern on a single photograph and between adjacent years. Each vegetation unit includes areas of several relative ages. This is partly because of the scale and simplicity of our mapping and partly because the units are often intertwined. Additional units would likely be delineated if larger-scale mapping was done.

Table I.13. Characteristics of vegetation map units

Map Unit	Appearance on Aerial Photographs	Geomorphic Interpretation	Relative Age
Shrubby Vegetation	Low vegetation; individual plants are not distinguishable; usually dense enough to cover surface continuously; often appear to follow old channels (e.g., have sinuous paths)	Once-active channels or bars that have become stable enough to have revegetated to the point of continuous, but low, vegetative cover; may include side channels (often in the deepest parts of the old channels)	Minimum age estimated to be a few years
Mixed Vegetation	Includes shrubby vegetation and scattered trees; shrubby vegetation often appears to be larger and more continuous than in the shrubby vegetation map unit; includes individual or small areas of trees (appear to be deciduous primarily)	Once-active channels or bars that have become stable enough to have revegetated to the point that shrubby vegetation has matured and trees are becoming large enough to be visible; may include side channels	Minimum age estimated to be about 10 years
Trees	Areas of nearly continuous trees, either deciduous, or conifer, or both; little other vegetation is visible	Surfaces that have not been part of the unvegetated channel in the recent past; the surfaces have been stable enough that trees have become established to the point that other vegetation types are subsidiary; surfaces may still receive some overbank flood flows, but not enough to disrupt tree growth; may include side channels	Minimum age estimated to be tens of years
Cleared	Areas are covered with grasses, primarily; areas appear to have been cleared by human activities; areas are generally outside of the unvegetated and slightly vegetated channels, and old channel map units	Areas cleared by human activity	Vegetation does not reflect surface age
Partially Cleared and (or) Regrowth on Previously Cleared Area	Areas that have several types of vegetation (e.g. open trees with grass, tree-covered areas and shrubby vegetation areas) in artificially appearing patterns (e.g., linear patterns that appear to roads)	Areas partially cleared by human activity, or areas that have been allowed to revegetate after clearing by human activities	Vegetation does not reflect surface age

3.1 Presence of trees

Presence of trees on vegetated surfaces within the HCMZ was interpreted to be indicative that the area had not been recently reworked by the river. These areas were important to our analysis to determine the stability of surfaces within the HCMZ, and their ability to impact channel processes. Vegetation map units containing trees were compared over time to look for trends (Figure I.1; Tables 14 and 15).

Table I.14. Area for mixed vegetation and trees within the HCMZ by reach for each year

Trees and mixed vegetation within HCMZ (Area, m^2)				
	Lower Reach	Middle Reach	Upper Reach DS	Upper Reach US
1939	362,218	562,631	35,030	127,820
1952	116,576	1,022,583	217,786	259,896
1962	220,543	714,726	75,947	-
1973	197,132	940,421	102,758	142,720
1982	129,658	655,871	64,664	79,595
1994	414,176	1,370,635	133,822	114,901
2002	726,583	2,164,847	256,468	284,247

Table I.15. Area of mixed vegetation and trees as percent of HCMZ area by reach for each year

Trees and mixed vegetation within HCMZ Percent of HCMZ)				
	Lower Reach	Middle Reach	Upper Reach DS	Upper Reach US
1939	32	10	4	20
1952	10	18	24	42
1962	17	12	8	-
1973	14	16	11	20
1982	9	10	7	11
1994	26	20	14	16
2002	43	31	26	40

3.2 Location of Persistently Vegetated Areas within the HCMZ From 1939 to 2002

A raster analysis was used to evaluate the number of times an area was mapped as containing trees between 1939 and 2002. Aerial photographs representing decadal times scales were used including 1939, 1952, 1962, 1973, 1982, 1994, and 2002. Areas stored in GIS files for the mixed and tree vegetation units for each year were converted to a raster using spatial analyst in ARC. A value of 1 was assigned to each pixel that was part of the either the mixed or tree map units and a value of 0 was assigned to areas outside of these two vegetation map units, but within the 2002 HCMZ. Rasters were summed using the raster calculator in spatial analyst in ARC to determine how many times a pixel (an area) had been part of a mixed or tree map unit (relatively stable vegetation) for the 10 years for which we have aerial photographs. Results of this analysis are shown in the main report (see Figure 23).

3.3 Ages of Vegetation Within the 2002 HCMZ

To determine the minimum age of vegetated areas containing trees, For example, if an area was within the mixed or tree map units in 2002 and 1994, then the age of that surface is assumed to be at least 8 years. Because of the number of years that are missing between the photographs that we used, it is possible that the vegetation had been destroyed and reestablished between photos. However, consistency among the years and evidence of channel occupation areas suggests that the vegetation was probably present between the years of the photographs. From this raster analysis, minimum ages for the surfaces within the HCMZ were estimated, and the area of each map unit was calculated in ARC (Tables 16 and 17). Results of this analysis are shown in graphical format in the main report (see Figure 25).

Table I.16. Areas for surfaces within each age map unit for each reach by year

Minimum Age	Area (m^2) for each age			
	Lower Reach	Middle Reach	Upper Reach DS	Upper Reach US
8	290706	641557	59683	33133
20	2735	126974	7762	8059
30	19505	21377	876	21230
40	33970	39161	0	0
50	0	73371	120	10477
63	17696	104774	5213	8627

Table I.17. Areas for surfaces within each age map unit as a percent of the total 2002 HCMZ area for each reach by year

Minimum Age	Percent of 2002 HCMZ			
	Lower Reach	Middle Reach	Upper Reach DS	Upper Reach US
8	17.05	9.30	6.16	4.66
20	0.16	1.84	0.80	1.13
30	1.14	0.31	0.09	2.98
40	1.99	0.57	0	0
50	0.00	1.06	0.01	1.47
63	1.04	1.52	0.54	1.21

3.4 Lengths of Vegetated Surfaces That Separate Active and Unvegetated Channels

Longitudinal lengths of vegetated surfaces were measured and computed to determine if a trend existed in the length of vegetated surfaces that separate either the active channel or unvegetated channel over time (Figure I.3; Tables I.18 and I.19). Center lines were mapped along the approximate center of vegetated surfaces that split the unvegetated channel on each year of photographs.

Table I.18. Lengths of vegetated areas that separate active channel paths.

	Length of Vegetated Areas that Separate the Active Channel (m)		
	Upper Reach	Middle Reach	Lower Reach
1939	0	1362	270
1952	0	993	0
1958	945	3444	0
1962	804	3218	1043
1973	551	1439	1265
1982	0	1800	280
1994	0	3490	0
1998	0	277	0
2001	110	518	0
2002	0	0	0

Table I.19. Lengths of vegetated areas that separate unvegetated channel paths (includes active channel path areas).

	Length of Vegetated Areas that Separate the Unvegetated Channel (m)		
	Upper Reach	Middle Reach	Lower Reach
1939	576	2740	0
1952	823	2788	0
1958	1237	1268	68
1962	0	2545	203
1973	908	2869	178
1982	905	2909	2020
1994	1418	4670	0
1998	810	3543	0
2001	603	2386	0
2002	641	3445	672

4.0 Vegetation Map Units Outside of the HCMZ

Almost all of the surfaces that bound the HCMZ have been thinned or cleared at least once since 1939. The types of vegetation that have been persistent or newly established since disturbance of each area affect the rate at which the channel can erode the surface, as well as the recruitment potential of large woody debris. An interpretation was made of the age and general characteristics of the vegetation on surfaces that bound the HCMZ. The vegetative cover classifications mapped are intended to qualitatively compare the types of vegetation and the potential for large woody debris recruitment along the Upper Quinault River (Figure I.4; Table I.20). The reader is referred to Chapter 2.8 of the Quinault River Watershed Analysis (1999) for a thorough discussion on the vegetation found within the Quinault River drainage. These mapping units were delineated on the 1939 and 2002 aerial photographs.

Table I.20. Interpretation of Vegetative Cover on Surfaces that Bound the HCMZ

Map Unit	Description
Mature	Canopy is generally heterogeneous in appearance, multi-storied, and of high-relief (tall) consisting predominantly of conifers. These areas are interpreted to represent late-successional forest stages. These areas are labeled as mature rather than old growth because timber harvesting was predominantly done through selective tree thinning leaving a substantial population of old growth (180 + years) but also disrupting the natural diversity and succession of forest. Although small remnants remain on the lower Holocene surface, the most expansive populations are found on bedrock and Pleistocene surfaces above the Holocene valley floor.
Mixed	Canopy is mottled in appearance, single- and multi-storied, and of moderate-relief consisting predominantly of deciduous trees. These areas are interpreted to represent middle- and late-successional forest stages. In many areas conifers were removed by extensive timber harvest (clear cutting) or by channel migration. The conifers were subsequently replaced by the deciduous trees. Most of the populations range in age between 35 and 50 years, but there are also populations of less than 30 years and greater than 60 years. Nearly all of the populations are on the Holocene surfaces with the more expansive populations being predominantly on the intermediate and upper surfaces.
Immature	Canopy is homogeneous in appearance, single-storied, and of low- to moderate-relief consisting of either conifers or deciduous trees. These areas are interpreted to represent early- and middle-successional forest stages which include both managed and unmanaged stands. Most of these populations are replacement stands that have grown within the last 35 years following timber harvesting and/or channel migration. The stands occur on all surfaces including Pleistocene terraces and bedrock.
Scattered	Canopy is heterogeneous in appearance, partially open, and of low- to moderate-relief. These areas are generally composed of deciduous trees, but also contain numerous conifers. No successional stages are interpreted because these areas appear to be actively managed. The tree populations contain an array of ages (from less than 20 years to greater than 65 years) depending on the stands origin (ie. homesteading, timber harvest, or channel migration). These stands are predominantly found on the Holocene surfaces.
Scrub	Canopy can be heterogeneous or homogeneous in appearance, predominantly open, and of low-relief. No successional stages are interpreted because these areas appear to be actively managed. Areas are comprised of brush that has grown-in following timber harvesting or channel migration. These areas can be found throughout the valley where clear cuts have been conducted and are common on the Holocene surfaces.
Grass	Canopy is homogeneous in appearance, open, and of very low-relief. No successional stages are interpreted because these areas appear to be actively managed. Areas are comprised of grasslands, pastures, and other openings that have been cleared by human disturbance or by channel migration. These areas are predominantly found on the Holocene surfaces.

5.0 Historical Bank Erosion along HCMZ

Expansion of the HCMZ between 1939 and 2002 was mapped to determine if a trend was present in the amount and location of erosion between 1939 and 2002 (Tables I.21 and I.22). The total area of bank erosion was also used as an input variable to the sediment budget (see Sediment Appendix). The HCMZ was delineated for each photograph year by observing changes in channel position and newly eroded areas, and then overlaid on the previous year HCMZ to identify areas that eroded between the photograph years (Figure I.5). A figure documenting locations and timing of erosion is presented in the main report (see Figure 17).

Table I.21 Lengths of the left (south) and right (north) HCMZ boundaries that were eroded between 1939 and 2002, and the percent of these lengths of the total 2002 HCMZ boundaries

Reach	Bank	Bank Length (m)	Length of Bank Eroded 1939-2002 (m)	Percent of Bank Eroded 1939-2002
Lower	Left	1900	736	39
	Right	1991	1660	83
Middle	Left	10,399	6989	67
	Right	11,069	7249	65
Upper	Left	4223	1224	29
	Right	3998	2576	64

Table I.22. Area of the left (south) and right (north) HCMZ boundaries that were eroded between 1939 and 2002 by year. (Note that only RK 14 to 16 is included for Upper Reach in 1962 and 1998)

Total Area (m^2) By Reach By Boundary (Left and Right)

	Lower Reach		Middle Reach		Upper Reach (Downstream Section)		Upper Reach (Upstream Section)	
	Left	Right	Left	Right	Left	Right	Left	Right
2001-2002	100	19068	25485	4916	0	0	0	0
1998-2001	0	4152	84296	4650	0	0	0	0
1994-1998	2297	3583	86388	7755	3847	0	0	0
1982-1994		119665	139161	164872	0	0	8474	0
1973-1982	445	17308	84950	238909	8426	0	0	0
1939-1973	--	--	--	--	--	--	--	33076
1962-1973	17297	161081	69318	43376	0	0	0	0
1958-1973	--	--	--	--	--	--	--	19952
1958-1962, Possible	--	--	--	--	--	--	--	8418
1958-1962	11830	8616	107754	84873	6969	10260	0	0
1952-1958	26616	5306	78012	105047	6933	13365	0	14399
1939-1952	15717	0	61590	114959	16679	24263	0	38910

Table I.23. Area of the left (south) and right (north) HCMZ boundaries that were eroded between 1939 and 2002. (Note that only RK 14 to 16 is included for Upper Reach in 1962 and 1998)

Reach	Bank	Bank Area (m^2)
Lower	Left	74,303
	Right	338,779
Middle	Left	736,954
	Right	769,357
Upper (Downstream Section)	Left	42,855
	Right	47,887
Upper (Upstream Section)	Left	8,474
	Right	114,755

As the HCMZ expands, it is possible that the channel has more area to occupy so it runs along the HCMZ boundary less, which results in less erosion. To test this hypothesis, the lengths of sections of the HCMZ that have coincided with the active channel and unvegetated channel of the Quinault River were compared between 1939 and 2002 (Figure I.6). Sections where the HCMZ boundary coincides with the active channel or unvegetated channel in that year were delineated for each reach in each year. Lengths were summed for each boundary (left and right) for the entire reach. The percentages of the total HCMZ boundary of these lengths for each year were computed in Excel. Results for the right and left HCMZ boundaries in the Lower Reach are presented in Tables 23 and 24, in Tables 25 and 26 for the Middle Reach, and in Tables 27 and 28 for the Upper Reach. Results for the active channel and unvegetated channel are presented separately. The active channel would be expected to have the deepest depths and highest velocities along the HCMZ boundary, but anywhere the unvegetated channel runs against the HCMZ could also result in significant erosion. Note that for the Lower Reach, the channel shifts to the north after 1973, such that it no longer runs along the left HCMZ boundary and vice versa for the right side. In the Upper Reach, a levee placed by 1973 has remained in place and prevented the channel from running along the left HCMZ boundary for most of the reach.

Table I.24. Lengths of active and unvegetated channel that coincide with the left HCMZ boundary for the Lower Reach

Lower Reach, Left Boundary				
	Active Channel Along Boundary		Unvegetated Channel Along Boundary	
Year	Lengths Total (m)	Percent of Total Bank	Lengths Total (m)	Percent of Total Bank
1939	294	18	717	44
1952	824	41	1074	53
1958	497	23	1015	48
1962	681	32	770	36
1973	407	21	512	26
1982	0	0	0	0
1994	0	0	0	0
1998	0	0	0	0
2001	0	0	0	0
2002	0	0	0	0

Table I.25. Lengths of active and unvegetated channel that coincide with the right HCMZ boundary for the Lower Reach

Lower Reach, Right Boundary				
	Active Channel Along Boundary		Unvegetated Channel Along Boundary	
Year	Lengths Total (m)	Percent of Total Bank	Lengths Total (m)	Percent of Total Bank
1939	310	16	310	16
1952	0	0	0	0
1958	0	0	0	0
1962	369	18	369	18
1973	256	12	727	34
1982	663	30	663	30
1994	213	9	1104	47
1998	39	2	1125	49
2001	223	9	983	41
2002	184	9	974	46

Table I.26. Lengths of active and unvegetated channel that coincide with the left HCMZ boundary for the Middle Reach

Middle Reach, Left Boundary				
	Active Channel Along Boundary		Unvegetated Channel Along Boundary	
Year	Lengths Total (m)	Percent of Total Bank	Lengths Total (m)	Percent of Total Bank
1939	4862	46	6630	63
1952	860	8	1909	18
1958	1951	19	3354	32
1962	2710	26	3668	35
1973	2362	23	3440	33
1982	1073	10	2256	22
1994	2510	24	3814	37
1998	1459	14	2663	26
2001	1671	16	3280	32
2002	2498	24	3563	34

Table I.27. Lengths of active and unvegetated channel that coincide with the right HCMZ boundary for the Middle Reach

Middle Reach, Right Boundary				
	Active Channel Along Boundary		Unvegetated Channel Along Boundary	
Year	Lengths Total (m)	Percent of Total Bank	Lengths Total (m)	Percent of Total Bank
1939	761	7	2569	23
1952	1689	15	2041	18
1958	2513	22	3502	31
1962	2471	22	4807	43
1973	1225	11	2287	20
1982	1701	15	4744	43
1994	2126	19	3630	32
1998	266	2	2540	23
2001	617	5	1951	17
2002	722	6	1768	16

Table I.I.28. Lengths of active and unvegetated channel that coincide with the left HCMZ boundary for the Upper Reach

Upper Reach, Left Boundary				
	Active Channel Along Boundary		Unvegetated Channel Along Boundary	
Year	Lengths Total (m)	Percent of Total Boundary	Lengths Total (m)	Percent of Total Boundary
1939	1559	37	2484	59
1952	0	0	279	7
1958	950	23	2010	48
1962	706	36	706	36
1973	1231	29	2364	57
1982	1398	33	1941	46
1994	1739	42	2305	55
1998	0	0	1363	32
2001	1770	43	1770	43
2002	1662	42	1662	40

Table I.I.29. Lengths of active and unvegetated channel that coincide with the right HCMZ boundary for the Upper Reach

Upper Reach, Right Boundary				
	Active Channel Along Boundary		Unvegetated Channel Along Boundary	
Year	Lengths Total (m)	Percent of Total Bank	Lengths Total (m)	Percent of Total Bank
1939	578	14	968	23
1952	151	4	151	4
1958	806	21	1380	36
1962	268	14	459	25
1973	0	0	0	0
1982	0	0	0	0
1994	0	0	324	8
1998	410	10	550	14
2001	0	0	527	13
2002	0	0	59	2

6.0 Delta Mapping

Mapping of the aerial extent of the Quinault River delta formed at the inlet to Lake Quinault was undertaken to estimate the amount of sediment being deposited in the delta for input into the sediment budget analysis (see Sediment Appendix). The sequential change of both erosion (reduction in delta size) and deposition (increase in delta size) were mapped for all historical maps and aerial photographs (Figure I.7), but only the deposition from 1939 to 2002 was used for the sediment budget. Delta areas below the water are visible on the aerial photographs and were mapped for each year. The Quinault River has occupied several different paths to Lake Quinault between RK 2 and the lake. Delta area was subdivided into four areas based on the different source channels that entered the lake at each of the four paths observed. A summary of the planform growth of each delta area is provided (Table I.29), along with computed areas (Tables I.30 to I.33).

Table I.30. Characteristics of the areas used in the mapping of the delta deposits

Year	Location of Low-flow Channel Relative to Deposition Areas (or Alluvial Fans)	Location of Low-Flow Channel Relative to Location in Previous Years
1897	Area 2, south side for main low-flow channel	South of the 1982 and 1994 low-flow channels
	Area 1, north side for a smaller low-flow channel	About the same location as the 1939 low-flow channel
1939	Area 1, north side	
1952	Area 1, near center	South of the location of the 1939 low-flow channel
1958	Area 1, near center	About the same location as the 1952 low-flow channel
1962	Split flow--one channel in Area 1, near center	About the same location as the 1952 and 1958 low-flow channels
	One channel in Area 2, near center	New location for the unvegetated channel
1973	Split flow--one channel in Area 1, near center	About the same location as the 1952, 1958, and 1962 (south branch) low-flow channels
	One channel in Area 2, near center	About the same location as the north branch of the 1962 low-flow channel
1982	Area 2, near center	About the same location as the north branches of the 1962 and 1973 low-flow channels
1994	Area 2, near center	About the same location as the 1982 low-flow channel
1998	Area 2, near center	About the same location as the 1982 and 1994 low-flow channels
2001	Area 2, near center and north part	About the same location as the 1982, 1994, 1998 low-flow channels and to the north of these channels
	Meander in the low-flow channel intersects the upper part of Area 3	Appears to be a narrow channel through the vegetation that leads to Area 3; a new location
2002	Area 3, near center	A new channel location; in about the same location as the narrow channel (not part of the unvegetated channel) in 2001

Table I.31. Changes in the delta in Area 1 between 1939 and 2002

Year	Type	Area (m^2)	Year	Type	Area (m^2)
1939	Deposition	82,769	1939	Erosion	0
1952	Deposition	51,840	1952	Erosion	3705
1958	Deposition	42,189	1958	Erosion	1825
1962	Deposition	5783	1962	Erosion	11,531
1962			1962	Erosion	5434
1973	Deposition	27,083	1973	Erosion	2250
1982	Deposition	1263	1982	Erosion	8648
			1982	Erosion	9753
1994	Deposition	1468	1994	Erosion	1028
1994	Deposition	2936			
1998	Deposition	4185			
2001	Deposition	1957			
2002	Deposition	920			
2002	Deposition	456			
Total	Deposition	222,849	Total	Erosion	44,174
Total	(Dep-Ero)	178,675			

Table I.32. Changes in the delta in Area 2 between 1939 and 2002

Year	Type	Area (m^2)	Year	Type	Area (m^2)
1939	Deposition	66,300			
1952	Deposition	3518			
1952	Deposition	1629			
1958	Deposition	10,073			
1962	Deposition	749	1962	Erosion	1690
			1962	Erosion	1960
1973	Deposition	5826	1973	Erosion	4513
1982	Deposition	31,894	1982	Erosion	1698
1994	Deposition	15,904	1994	Erosion	12,354
1994	Deposition	1246			
1998	Deposition	679			
1998	Deposition	28,906			
2001	Deposition	1545			
2001	Deposition	8268			
2002	Deposition	3118			
2002	Deposition	316			
2002	Deposition	1556			
2002	Deposition	935			
Total	Deposition	182,463	Total	Erosion	22,215
Total	(Dep-Ero)	160,248			

Table I.33. Changes in the delta in Area 3 between 1939 and 2002

Year	Type	Area (m^2)	Year	Type	Area (m^2)
1939	Deposition	20,843	1939	Erosion	0
1973	Deposition	7021	1973	Erosion	0
1982	Deposition	5048	1982	Erosion	1763
1994	Deposition	4905	1994	Erosion	0
1998	Deposition	661	1998	Erosion	0
2002	Deposition	0	2002	Erosion	1484
Total	Deposition	38,478	Total	Erosion	3247
Net Change		35,232			

Table I.34. Changes in the delta in Area 4 between 1939 and 2002 (Note that no erosion was observed in this area)

Year	Type	Area (m^2)
1939	Deposition	12,772
1952	Deposition	1935
1962	Deposition	605
1973	Deposition	18,839
1982	Deposition	12,687
1982	Deposition	1915
1994	Deposition	2406
1994	Deposition	6705
1998	Deposition	1774
2002	Deposition	5460
Total	Deposition	65,098
Net Change		65,098

7.0 Human Disturbances

A cursory evaluation of areas that were interpreted to be thinned or cleared on each aerial photograph available was done to determine the general extent and timing of disturbance to the vegetation within the Upper Quinault River Valley (FigureI.8). This mapping is not intended to be a thorough documentation of logging and would need to be further refined for computation purposes. However, it provided an adequate qualitative interpretation of the extent and timing of logging activities over the last century.

Additional mapping of roads, bank protection, engineered log jams, levees, bridges, culverts, and other unique human placed features were also mapped. In many cases these features were observed in the field or on a particular aerial photograph, but the exact construction date is not known. A map of these features known to exist in 2002 is provided in the main report (see Figure 32).

An additional mapping unit was delineated on the 2002 aerial photograph that estimates the minimum time period for which surfaces binding the HCMZ were last disturbed in some way. For example, if a surface was relatively undisturbed in 1939, logged in 1952, and has remained cleared since 1952, the 2002 map unit would show the area as last disturbed 50 years ago. If a surface was cleared by the 1939 aerial photograph and has remained cleared, it would show the last disturbance as 65 + years ago. The disturbance mapping was combined with vegetation mapping of terrace surfaces to estimate minimum ages of trees present in 2002 on surfaces binding the HCMZ.

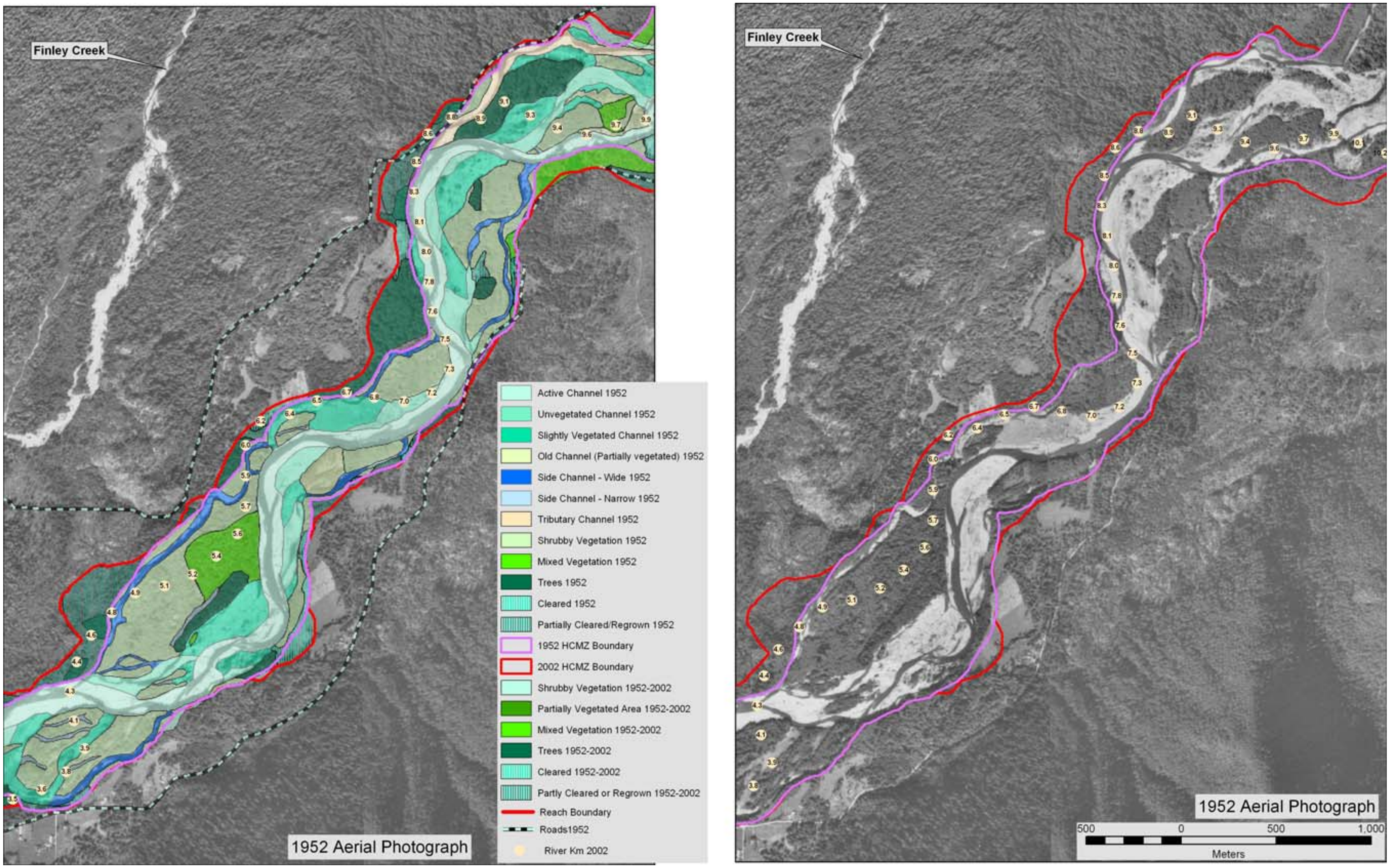
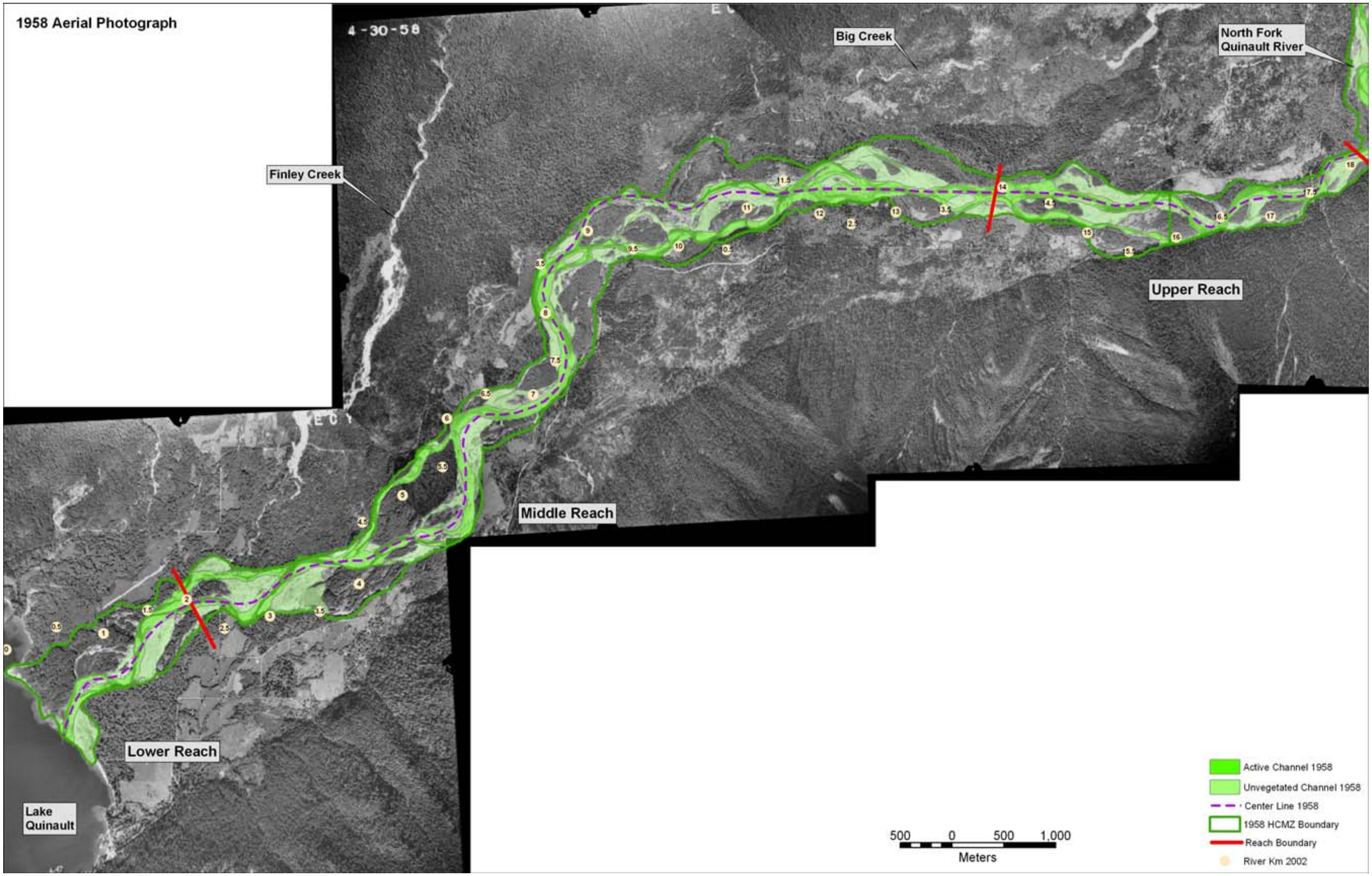


Figure I.1. An example of the channel and vegetation map units delineated within the HCMZ on a portion of the 1958 aerial photograph.



FigureI.2. Average widths were calculated for the active channel and unvegetated channel (includes the active channel) for each year of photographs. The average widths were calculated by dividing the area of each channel type by the length of a line drawn

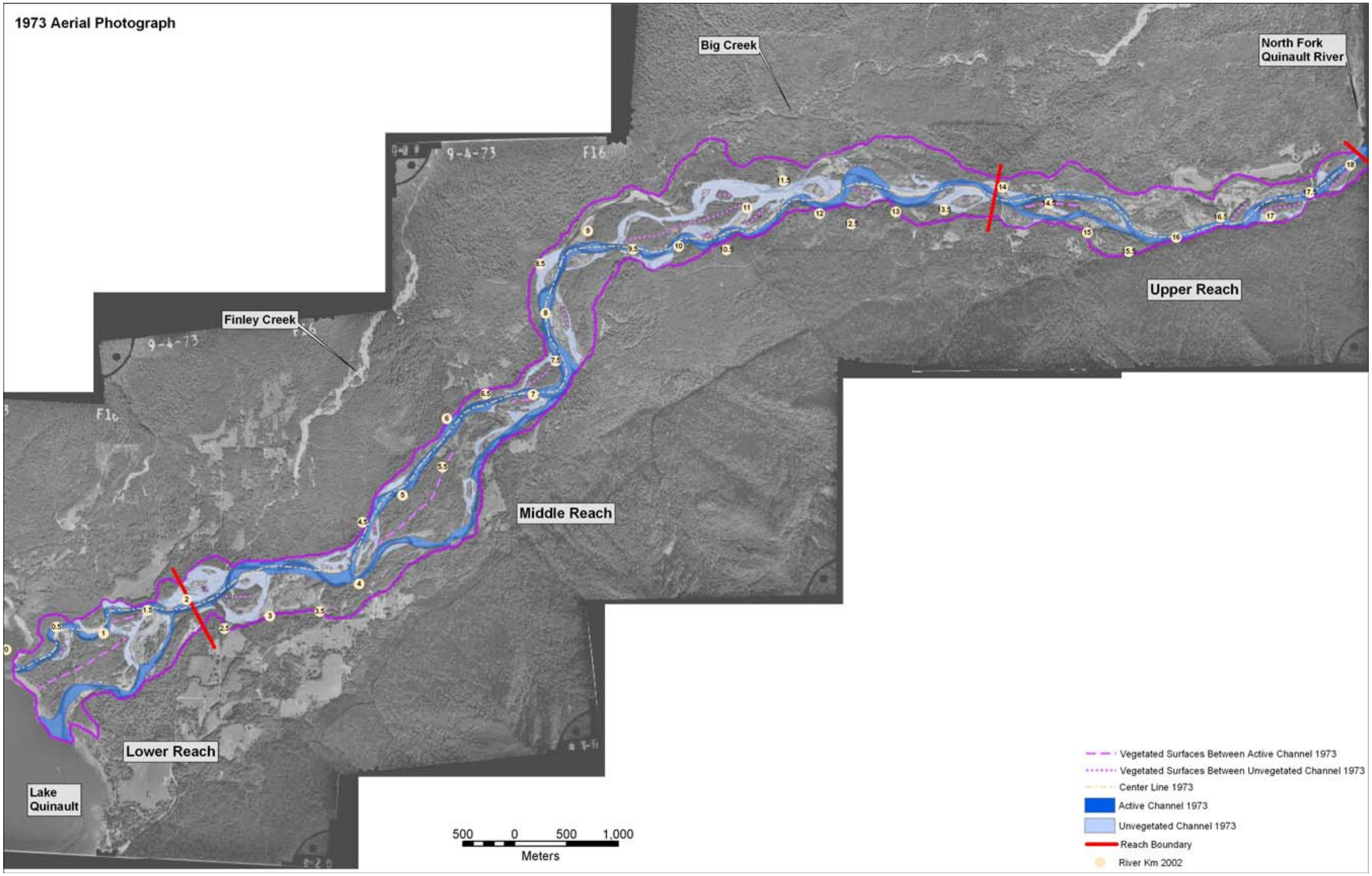


Figure I.3. Lengths of vegetated surfaces that separated the active and unvegetated channels were mapped for each year of photographs. The lengths of the separating vegetated surfaces were compared to the entire length of the reach as represented by the center line of the channels, as discussed in Section 2.1. This figure shows the 1973 channel units and center line as an example of these calculations.

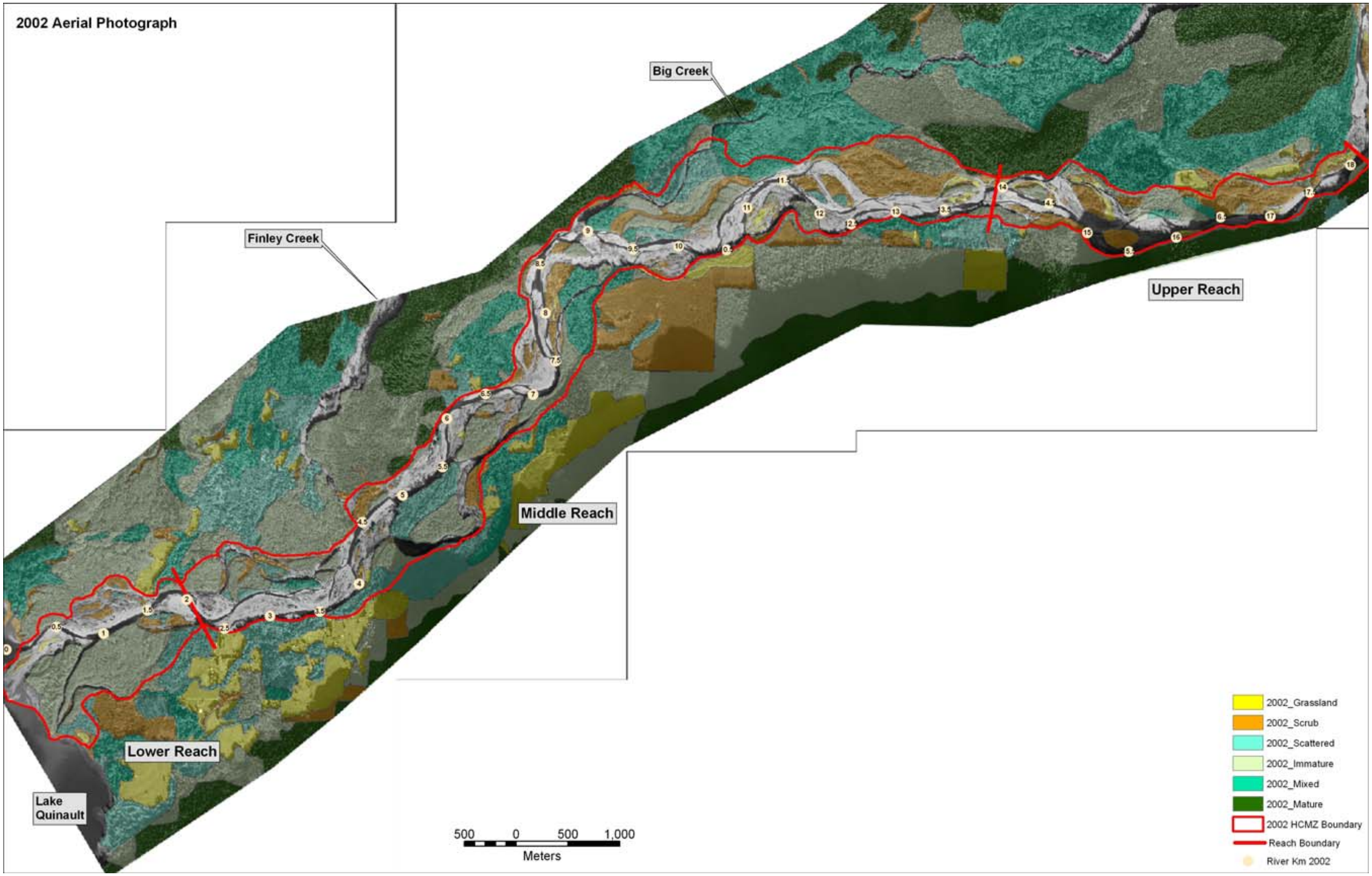


Figure I.4. Vegetation units that were mapped primarily outside of the HCMZ using the 2002 aerial photographs.

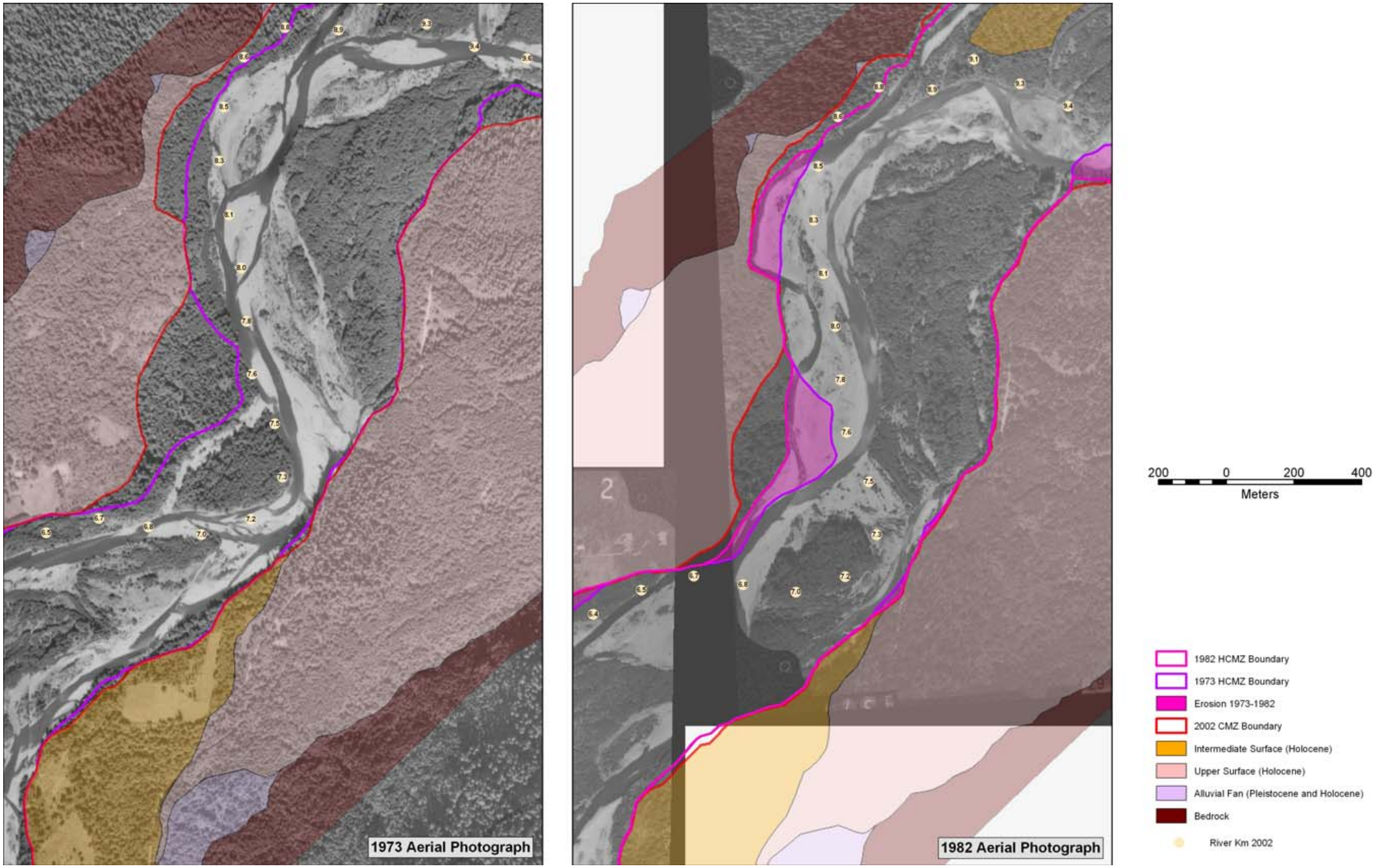


Figure I.5. Areas that were incorporated into the HCMZ between years of photographs were delineated and their areas were calculated in Arc. In this way, expansion of the HCMZ between 1939 and 2002 was documented. This figure shows an example of HCMZ e

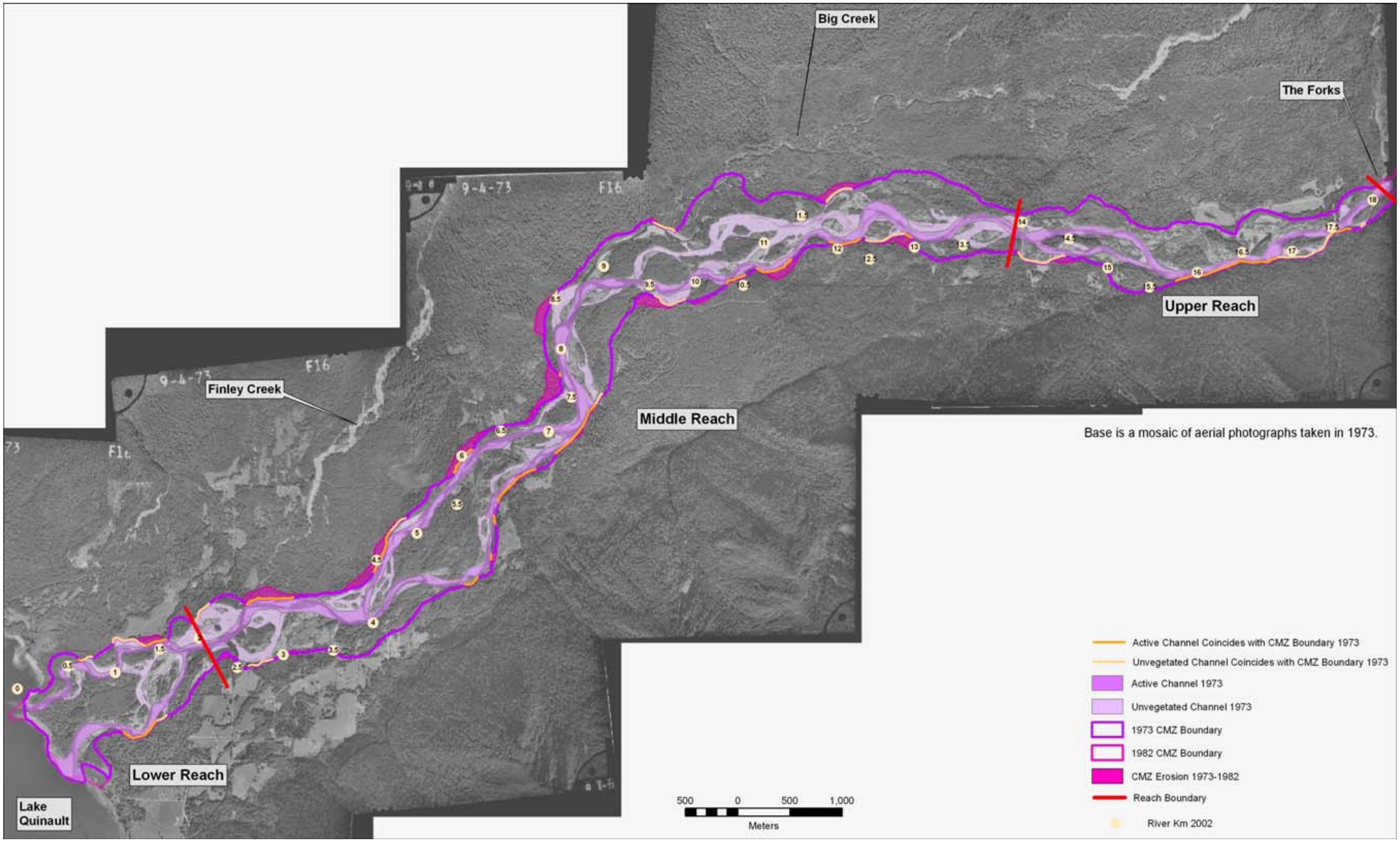


Figure I.6. Lengths of the left and right HCMZ boundaries that coincide with the active and unvegetated channels were mapped for each year of photographs. The lengths were summed for each boundary in each reach by year, and the percent of the total HCMZ

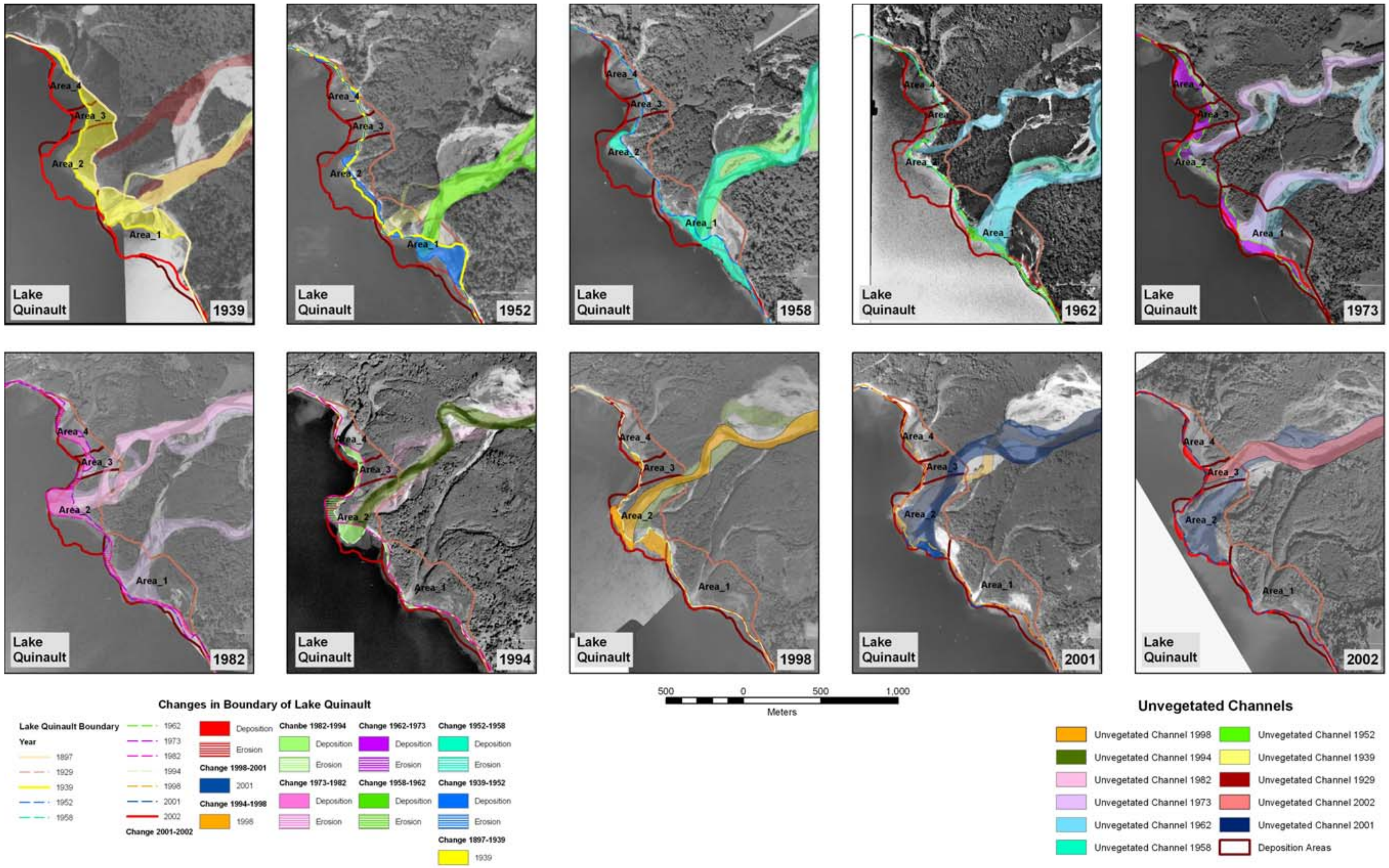


Figure I.7. Mapping of changes in the delta area between 1939 and 2002. The delta area was subdivided into 4 areas based on the source of the sediment entering Lake Quinault.

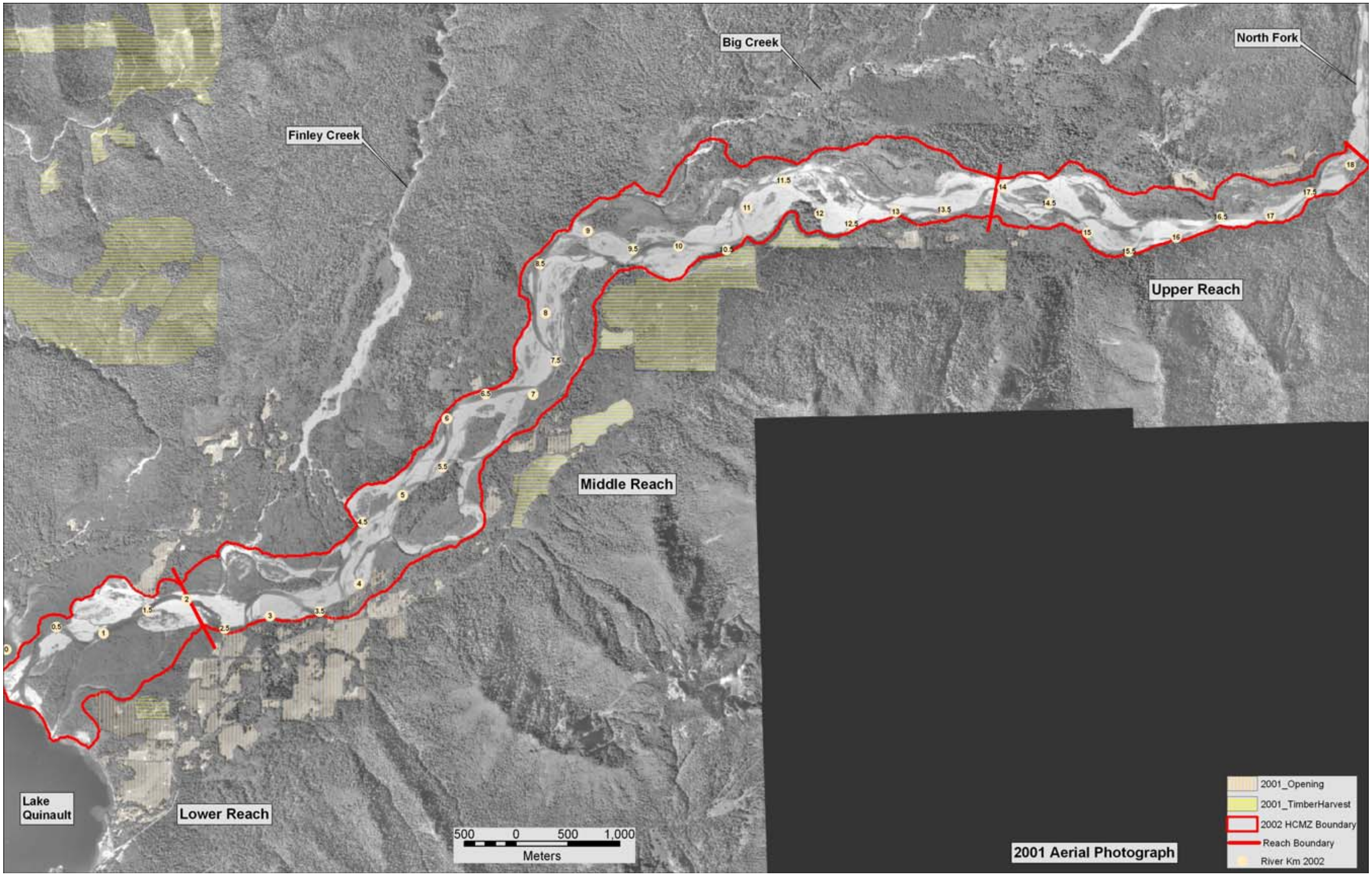


Figure I.8. An example of cleared and harvested areas that were mapped outside of the HCMZ using the 2001 aerial photographs. Mapping of this type was done for the following years: 1939, 1958, 1962, 1973, 1982, 1998, and 2001.